

CLAIMS

What is claimed is:

- 1 1. A two-channel frequency-offset estimator to generate a frequency offset
2 estimate comprising:
3 a first autocorrelation element to perform a first autocorrelation on a serial
4 symbol stream of training symbols delayed by a first duration to produce a first
5 correlation output;
6 a second autocorrelation element to perform a second autocorrelation on
7 the serial symbol stream delayed by a second duration to produce a second
8 correlation output;
9 a first moving average element to perform a first moving average on the
10 first correlation output for use in generating a first phase shift estimate; and
11 a second moving average element to perform a second moving average on
12 the second correlation output for use in generating a second phase shift estimate.
- 1 2. The frequency-offset estimator of claim 1 wherein the frequency offset
2 estimate is a fine frequency offset estimate and is applied to a phase rotator to
3 rotate the phase of data symbols of an orthogonal frequency division multiplexed
4 (OFDM) packet prior to performing a Fast Fourier Transform (FFT).
- 1 3. The frequency-offset estimator of claim 1 wherein the first duration is a
2 duration of one of the training symbols, and the second duration is twice the first
3 duration, and wherein the first moving average element performs the first moving
4 average over approximately one and a half durations, and the second moving
5 average element performs the second moving average over approximately one-half
6 durations on the second correlation output.
- 1 4. The frequency-offset estimator of claim 1 further comprising a phase
2 correction element to adjust the second phase shift estimate by a multiple of 2π
3 when a difference between the first and second phase shift estimates exceed π .

1 5. The frequency-offset estimator of claim 1 further comprising a
2 summator to combine the first and second phase shift estimates to generate a
3 frequency offset estimate, wherein the summator multiplies the first phase shift
4 estimate by $w_1/2\pi T$ to generate a first weighted frequency estimate, and multiplies
5 the second phase shift estimate by $w_2/4\pi T$ to generate a second weighted
6 frequency estimate, and combines the first and second weighted frequency
7 estimates to generate the frequency offset estimate, wherein w_1 and w_2 are weights
8 and T is the duration.

1 6. The frequency-offset estimator of claim 4 wherein the frequency offset
2 estimate is applied to a phase rotator to shift a phase of symbols of an orthogonal
3 frequency division multiplexed (OFDM) packet prior to performing a Fast Fourier
4 Transform (FFT), the phase shift being held constant for performing the FFT on
5 subsequent data symbols of the OFDM packet.

1 7. The frequency-offset estimator of claim 1 wherein the training symbols
2 are sampled long training symbols comprised of a plurality of modulated
3 subcarriers having known training values.

1 8. The frequency-offset estimator of claim 7 wherein the long training
2 symbols are periodic having a period equal to the duration.

1 9. The frequency-offset estimator of claim 1 wherein further comprising;
2 a conjugation element to generate a complex conjugate of the training
3 symbols; and
4 first and second delay elements to delay the training symbols at least by the
5 duration.

1 10. The frequency-offset estimator of claim 1 wherein the first
2 autocorrelation element multiplies the training symbols with a complex conjugate
3 of the training symbols delayed by approximately one duration, and

4 wherein the second autocorrelation element multiplies the symbol stream of
5 training symbols with a complex conjugate of the symbol stream of training
6 symbols delayed by approximately two durations.

1 11. The frequency-offset estimator of claim 1 wherein the first duration is
2 a duration of one of the training symbols, and the second duration is twice the first
3 duration, and wherein the first moving average element performs a first
4 integration over 1.5 symbol durations and produces a first complex value, wherein
5 the second moving average element performs a second integration over 0.5
6 symbol durations and produces a second complex value,
7 and wherein the frequency-offset estimator further comprises:
8 a first angular extraction element to extract the first phase shift estimate
9 from the first complex value; and
10 a second angular extraction element to extract the second phase shift
11 estimate from the second complex value.

1 12. The frequency-offset estimator of claim 1 wherein the frequency offset
2 estimate is a coarse frequency offset estimate to adjust a frequency for down-
3 converting an IF input signal to the serial symbol stream.

1 13. The frequency-offset estimator of claim 12 wherein the serial symbol
2 stream is comprised of sampled short training symbols modulated on a portion of
3 a plurality of subcarriers, the short training symbols having known training values.

1 14. A method for frequency synchronization of an orthogonal frequency
2 division multiplexed (OFDM) signal comprising:
3 generating a frequency offset estimate using first and second phase shift
4 estimates, the first phase shift estimate generated from a serial symbol stream of
5 training symbols with the symbol stream delayed by approximately a first
6 duration, the second phase shift estimate generated from the serial symbol stream
7 with the symbol stream delayed by a second duration.

1 15. The method of claim 14 wherein generating comprises:
2 autocorrelating the serial symbol stream of training symbols with the
3 symbol stream delayed by approximately the first duration to produce a first
4 correlation output;
5 autocorrelating the serial symbol stream with the symbol stream delayed
6 by the second duration to produce a second correlation output;
7 integrating the first correlation output to generate the first phase shift
8 estimate;
9 integrating the second correlation output to generate the second phase shift
10 estimate; and
11 combining the first and second phase shift estimates to generate the
12 frequency offset estimate.

1 16. The method of claim 15 further comprising:
2 rotating a phase of data symbols of an OFDM packet by applying the
3 frequency offset estimate to a phase rotator to rotate the phase of input symbols by
4 an amount of phase shift based on the frequency offset estimate prior to
5 performing an FFT on the data symbols; and
6 holding the amount of phase shift constant for performing the FFT on the
7 data symbols.

1 17. The method of claim 15 wherein the first duration is a duration of one
2 of the training symbols, and the second duration is twice the first duration, and
3 wherein integrating the first correlation output includes integrating the first
4 correlation output over approximately one and a half durations, and
5 wherein integrating the second correlation output includes integrating the
6 second correlation output over approximately one-half durations.

1 18. The method of claim 14 further comprising adjusting the second phase
2 shift estimate by a multiple of 2π when a difference between the first and second
3 phase shift estimates exceed π .

1 19. The method of claim 15 wherein combining includes multiplying the
2 first phase shift estimate by $w_1 / 2\pi T$ to generate a first weighted frequency
3 estimate; multiplying the second phase shift estimate by $w_2 / 4\pi T$ to generate a
4 second weighted frequency estimate; and summing the first and second weighted
5 frequency estimate to generate the frequency offset estimate, wherein w_1 and w_2
6 are weights and T is the duration.

1 20. The method of claim 14 wherein the training symbols are sampled long
2 training symbols comprised of a plurality of modulated subcarriers having known
3 training values.

1 21. The method of claim 14 further comprising:
2 generating a complex conjugate of the training symbols; and
3 delaying the training symbols at least by the duration.

1 22. An orthogonal frequency division multiplexed (OFDM) receiver
2 system comprising:
3 a dipole antenna to receive signals that include an OFDM packet;
4 an RF receive unit to convert the OFDM packet to a stream of symbols;
5 a data symbol processing unit to perform a Fast Fourier Transform (FFT)
6 on the stream of symbols to generate a decoded bit stream; and
7 a two-channel frequency offset estimator to generate a frequency offset
8 estimate using training symbols of the stream of symbols to rotate a phase of data
9 symbols of the OFDM packet prior to performing the FFT.

1 23. The OFDM receiver system of claim 22 wherein the data symbol
2 processing unit includes a phase rotator responsive to the frequency offset
3 estimate, and wherein the two-channel frequency offset estimator includes:
4 a first autocorrelation element to perform a first autocorrelation on a
5 symbol stream of training symbols delayed by a first duration to produce a first
6 correlation output;

7 a second autocorrelation element to perform a second autocorrelation on
8 the symbol stream of training symbols delayed by a second duration to produce a
9 second correlation output;
10 a first moving average element to perform a first moving average on the
11 first correlation output for use in generating a first phase shift estimate;
12 a second moving average element to perform a second moving average on
13 the second correlation output for use in generating a second phase shift estimate;
14 and
15 a summator to combine the first and second phase shift estimates to
16 generate the frequency offset estimate.

1 24. The OFDM receiver system of claim 23 wherein the first duration is a
2 duration of one of the training symbols, and the second duration is twice the first
3 duration, and wherein the first moving average element performs the first moving
4 average over approximately one and a half durations, and the second moving
5 average element performs the second moving average over approximately one-half
6 durations on the second correlation output.

1 25. The OFDM receiver system of claim 23 wherein the data symbol
2 processing unit further includes a phase correction element to adjust the second
3 phase shift estimate by a multiple of 2π when a difference between the first and
4 second phase shift estimates exceed π .

1 26. The OFDM receiver system of claim 23 wherein the summator
2 multiplies the first phase shift estimate by $w_1/2\pi T$ to generate a first weighted
3 frequency estimate, and multiplies the second phase shift estimate by $w_2/4\pi T$ to
4 generate a second weighted frequency estimate, and combines the first and second
5 weighted frequency estimates to generate the frequency offset estimate, wherein
6 w_1 and w_2 are weights and T is the duration.

1 27. An article comprising a storage medium having stored thereon
2 instructions, that when executed by a computing platform, result in:

3 autocorrelating a serial symbol stream of training symbols with the symbol
4 stream delayed by approximately a first duration to produce a first correlation
5 output;
6 autocorrelating the serial symbol stream with the symbol stream delayed
7 by a second duration to produce a second correlation output;
8 integrating the first correlation output to generate a first phase shift
9 estimate;
10 integrating the second correlation output to generate a second phase shift
11 estimate; and
12 combining the first and second phase shift estimates to generate a
13 frequency offset estimate.

1 28. The article of claim 27 wherein the instructions further result in
2 rotating a phase of data symbols of an orthogonal frequency division multiplexed
3 (OFDM) packet by applying the frequency offset estimate to a phase rotator to
4 rotate the phase of input symbols by an amount of phase shift based on the
5 frequency offset estimate prior to performing an FFT on the data symbols.

1 29. The article of claim 29 wherein the instructions further result in:
2 holding the amount of phase shift constant for performing the FFT on the
3 data symbols,
4 and resulting in frequency synchronization of an orthogonal frequency
5 division multiplexed (OFDM) signal that includes the OFDM packet.